

BIBLIOGRAPHY

THE Literature on the relations of Religion and Science is enormous and extends over every modern literary language. Here we shall only give a few recent English books on the subject.

The fullest summary of the modern standpoint is a work edited by Joseph Needham, *Science, Religion and Reality*, London (Sheldon Press), 1926. It contains chapters by a number of writers with an Introduction by Lord Balfour and a Conclusion by the Dean of St. Paul's. A large section of the present work is contained in an essay contributed by its author to that volume.

A. D. White, *History of the Warfare of Science with Theology in Amsterdam*, 2 vols., 1896, appears to the present writer to be lacking in depth despite its learning. It contains, however, a mass of valuable references.

Stimulating works containing bibliographical material are those of J. B. Bury, *A History of Freedom of Thought*, 1913, and *The Idea of Progress*, 1920. Henry Osborn Taylor, *Freedom of the Mind in History*, 1923, contains much of value.

The two largest works that deal with the modern position, written from different standpoints, are A. W. Benn, *History of English Rationalism in the Nineteenth Century*, 2 vols., 1906, and J. T. Merz, *European Thought in the Nineteenth Century*, 5 vols., Third edition, 1907. Interesting sidelights are thrown on the subject by R. H. Murray, *Science and Scientists in the Nineteenth Century*, 1926.

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RELIGION & SCIENCE
CONSIDERED IN THEIR HISTORICAL
RELATIONS

By CHARLES SINGER



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RELIGION AND SCIENCE

§ 1

EARLY RELIGIONS

LET us begin our discussion by glancing at the religious practices and beliefs of the savage. We say religious *practices and beliefs* because, on this level, man cannot be said to profess *a religion*. We observe that the religious beliefs and practices of a savage tribe are seldom sharply marked off from those of neighbouring tribes, nor do the legends and beliefs of such peoples provide anything in the way of a complete explanation of life. An actual religious system implies a great mental advance from the savage state. It involves the advent of what we may call 'mental coherence,' an attempt to understand the world as a whole and an acceptance of the view that the world, being comprehensible, must have certain governing principles which can be widely traced through it.

Such religions or systems of religion we encounter in the Empires of the ancient East. Egypt, for instance, provides us with a whole series of *systems* of theology. The later Egyptian religion is a syncretic product. In it the series of earlier systems have become fused and often confused. As with nearly all great religions the final result is a patchwork. Yet it is evident that each system in its day was an attempt to explain Man and the World and their relation to each other. Each system deals, too, with man's origin and his fate. Thus it covers the whole field not only

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of what we now call religion but also of what we now call science. In other words, religion and science are both present but are so interconnected that they cannot be separated from each other.

A similar system or series of systems is traceable in the beliefs of the Mesopotamian peoples. Best known to us, however, is the kindred religion which arose in Palestine. In the beliefs of the Hebrews, as in those of the Egyptian and Mesopotamian folk, we may detect successive attempts to "cover the phenomena," the actual succession being still traceable in the composite record that has come down to us. It is important for us to note that in the early Hebrew religious system, as in the other religions of the ancient East, there is no trace of a suggestion that natural knowledge, or any conception of the nature of the world, was regarded as an impediment or handicap to religion. Nevertheless, even in this stage we see man giving reasons for the faith that is in him. Religions on this level seek to justify themselves and to explain their origin and nature in a manner that shall conform with observed phenomena. There is thus a tendency to develop ritual into a legal system, and attempts are consciously made to fix tradition.

This is the stage that clearly corresponds to the present needs of the vast majority of civilised mankind, and is to a large extent expressed to-day by the great living religions. These have all sought to provide their followers with an explanation of the world in which they live. Such cosmologies were once the very bases of the appeal that these religions made to the rationalising mind. Historically we now know that on another mental level such cosmologies form an obstacle where they were once an aid.

EARLY GREEK THOUGHT

It was, however, neither in Palestine, nor in Mesopotamia, nor in the valley of the Nile that the scientific element was first differentiated from the religious. That task was the work of the Hellenes.

When we examine the literary monuments of the classical culture—of which we are the heirs and the Greeks the earlier and main intellectual representatives—we cannot fail to be impressed by the vastness of its interests and the enormous mental energy that it displays. Considering these things, the comparative backwardness of the religious development of that culture is a very striking feature. Greek religion never reached the rational standard of the Hebrew religion. Thus no complete and worked-out Greek cosmology, incorporated in a religious atmosphere, has come down to us. The popular Greek religion, in fact, never reached the coherent level of the Hebrew, or reached it only in later times and then in competition with philosophical or other systems which themselves made religious claims, and notably in contact with Christianity.

It has often been remarked that the Greeks had no Canon of sacred literature. Yet even more noteworthy is it that in the whole corpus of pagan classical literature—Greek and Latin—there has survived no work by a priest. The relatively low grade of their religion is in contrast to their scientific and philosophical development for which, as some think, way was thus made. At a remarkably early stage in their development the Greeks observed not only that their

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world was subject to laws, but that, by investigation, these laws are ever further and further discoverable. It was with the Greeks, and especially with the Ionian Greeks, that the scientific idea was born, and it can be traced back among them with some clearness to the sixth century B.C.

✓ In order to avoid misunderstanding it is necessary to enlarge a little on this statement that the scientific idea begins with the Ionian Greeks of the sixth century B.C. It is not suggested that the careful and accurate observation of nature began with them—in such observation every hunter must be an expert, and we have evidence of its existence far back in palæolithic times. Nor is it even suggested that the Ionian Greeks were the first to formulate general laws concerning natural phenomena, for the Egyptians were in possession of certain mathematical laws, for instance, as early as 1700 B.C., and doubtless earlier still. The Ionian, Thales of Miletus (c. 640- c. 546 B.C.), founder of Greek geometry and astronomy, predicted the eclipse visible in Asia Minor on May 28, 585 B.C., but he predicted it from data of Mesopotamian origin. There were astronomical observatories in the great cities of the Euphrates valley as far back as the eighth century B.C., when professional astronomers were taking regular observations of the heavens. Similarly, rational Greek medicine can be shown to have been preceded by Egyptian writings.

✓ It was thus not the *practice* of science which the Greeks invented, but the *scientific idea*, the conception that the world was knowable in as much and in so far as it could be investigated. In ancient times this idea led to a special philosophical point of view and to some limited amelioration of man's material lot. In modern times it has led to complete transformation of our mode of life, to a profound modification of the interrelations of peoples, to an alteration in our attitude to each other and to the world around us, to a

revolution in our social system and to a fundamental disturbance in the group of ideas that we class as religious. It would be idle to claim that these changes have been always and everywhere to the good. We believe, however, that an impartial survey of the general effects of the scientific idea upon men's minds and hearts throughout the ages will result in an overwhelming verdict in favour of science as a very beneficent and humanising instrument. In helping man to gain a clear idea of the knowable world, science has also helped him to understand his fellow-man. Moreover, while it has made him wiser, more understanding and more human, it has also ultimately developed in him a sense of the mystery and vastness of the world that not even religion has been able to bestow so fully.

To give any adequate account of the development of ancient conceptions of the knowable world would involve a description of the whole course of Greek thought. Here we are only concerned with the process by which rational ideas became applied to the known physical universe, and with the bearing of this process on religious thought. The process is precisely that which we nowadays call *science*, a department which in antiquity was, however, by no means always clearly separated from other modes of thought and particularly was linked with philosophy. Among the Greek 'philosophers' who worked before the close of the fifth century B.C. we see how these rational ideas came gradually to be universally applied. Far back in the history of Greek thought we see men feeling their way to an interpretation of that universal principle which they distinguish as *physis*, a word which survives in our modern terms, *physics*, *physiology*, *physical*, *physician*, etc.

Physis meant at first *growth* or *development* the essential element of all existence, and it was specially applied to living things. Gradually there dawned the

idea that this growth followed definite rules which differed in different cases but in which a common character might be distinguished. By a simple process of transference *physis* came to be regarded as this rule or manner of development itself, and so came to mean something near to what we now call a *natural law*.

As knowledge grew, these rules or laws were traced more and more widely, and the philosophers tried to discern that which was behind them. It was inevitable that some should see there an individual and personal power. Thus *physis* was given an existence apart from the individual laws which had been traced. *Physis*, in fact, was more or less personified. Had the religion of the Greeks advanced along rational lines with their other departments of thought, *Physis* would doubtless have been raised to the rank of a god. Although the greatest among the Greek investigators of nature never took this step, yet the tendency to do so is distinguishable through large departments of Greek thought. This tendency is, in a sense, a combination of the religious, philosophic and scientific standpoints.

There is an incident in the later history of the idea represented by the word *physis*, which had a deep influence on the subsequent development of thought. When the Greek world became absorbed into the Roman Empire, Greek thought gradually assumed a Latin dress. The philosophical term *physis* was then mistranslated by the word *natura*. The Latin word contains not so much the idea of *growth* as of *birth*. Emphasis was thus transferred from the idea of *law* to the idea of *origin*. This we can clearly see if we contrast two works in which these words are used. Thus we have a Greek work of about 400 B.C., ascribed to Hippocrates, entitled *On Man's Physis*—i.e., 'On the way things happen in man.' It is a scientific attempt to explain a limited part of the universe, to

wit man's body, by a series of general ideas based on observation. We can compare this with the approach of the Latin philosopher Lucretius, who died about 55 B.C., and wrote *De rerum natura*—i.e., 'On the origin of things in general,' a philosophical thesis which seeks to explain the entire workings of the universe on a particular hypothesis about its origin.

In glancing at these two works we perceive that we have before us two entirely different and perhaps incompatible things. On the one hand is a work of pure science in which the investigator is interested only in a particular problem and explains it in terms which might obtain universal assent. On the other hand is a work pertaining to the nature of philosophy or religion—according to our manner of approach—in which the writer is less interested in the solution of any special problem than in finding a common element at the back of all problems.

The position gives us the key to some of the subsequent relations of science on the one hand to religion and philosophy on the other. It is the business of the man of science to investigate only such parts of nature as are in a field that he himself specifically marks off. In examining this field he traces laws, seeing essential unity behind apparent diversity. There is, however, another class of thinker who is no less occupied in seeking unity in diversity, but who is concerned with a much wider field than is the working man of science. The philosopher may well adopt the conclusions of the scientific observer. Nevertheless he is occupied in a different task and applies a different method, and his method is not that of religion.

One of the reasons why ancient science was not more successful in solving specific problems was precisely that ancient thinkers were less able than ourselves to forsake the great general problems or, indeed, to differentiate the one type of investigation from the other. Some there were, however, in antiquity who

did succeed in distinguishing between the two categories. The first writer to make clear in practice this separation between science and philosophy is said to have been the physician, Hippocrates of Cos. If, therefore, Greek philosophy—or a department of it—sought to give a rational basis to our knowledge of the world, it was Greek medicine that first put that rational basis to the test.

There is one great monument of the rational spirit in medicine to which we must specially refer. This book was composed a little before 400 B.C. It is the first work in which the scientific is clearly set over against the religious point of view, and it deals with what is described as *The Sacred Disease*, the condition that we nowadays call epilepsy.

We are here not at all concerned with the hypothesis proposed by the author in his attempt to explain the sacred disease. The point for our purpose is that he is led to his hypothesis by a general law which he thinks he has discovered behind the diverse phenomena of the disease. The book presents to the reader two opposing views of the nature of disease. One view, which is rejected, is based on that form of religion in which the more striking phenomena are ascribed to the action of supernatural powers. The other view, claiming the disease as the result of the inevitable action of a natural law, may be classed as a scientific hypothesis. The book contains a hint that such laws are of universal application.

The essential part of this most remarkable work we render in an abbreviated form.

“As regards the disease called *Sacred*, I believe it to be no more divine than other diseases, but like them to have its own *physis*. Men regard its origin as divine from ignorance and wonder, since it is a peculiar condition and not readily understood. Yet if reckoned divine merely because wonderful, then instead of one there would be many sacred diseases.

“ To me it appears that they who refer such conditions to the gods are but as certain charlatans who use divinity to cloak their ignorance. They give out the disease to be sacred and adopt a treatment that shall be safe for themselves, whatever happen. They apply purifications and incantations and all manner of charlatanry, but mark! they also enforce abstinence from unwholesome food. All these things they enjoin, they say, with reference to the divinity of the disease. If the patient recover, theirs is the honour; if he do not, it is the god, not they, that is to blame, seeing they have administered nothing unwholesome.

“ But consider! Surely if certain diets aggravate the disease and it be cured by abstinence, then the god is *not* the cause of the disease, and they who seek thus to cure it are, by this very act, showing that it is not divine. Nay, more, their assertion of its sacredness and divinity savours of impiety, as though there were no gods.

“ If these fellows professed to bring down the moon, to darken the sun, or to induce storms, should we not accuse them of impiety, whether they claimed this power as derived from the sacred mysteries or from any other knowledge? Nay, more, even if they could do these things, I, for my part, should still not believe there was anything divine therein, since the divine would have been overpowered by human knowledge and have become subject thereto.

“ Surely then this disease has its proper nature and causes whence it originates, even as have other diseases, and it is curable by means comparable to their cure. It arises, like them, from things which enter and quit the body, such as cold, the sun, and the winds, things which are ever changing and never at rest. Are such things divine or no? As you will, for the distinction matters not, nor is there need to make this distinction anywhere in Nature, wherein all things are alike divine and all are alike natural, for

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have not all a *physis* which can be found by those who seek it steadfastly?"

A clear conception of natural law has here emerged. The writer is entirely without opposition to the doctrine of the existence of a separate and ultimate cause of all things, but he refuses to confuse that cause with natural law. He has distinguished sharply between science on the one hand and religion on the other.

Towards the end of the fifth century B.C. there were several schools of thought in Greece that claimed to explain the material universe. One of these schools, that of Democritus, was very important for its influence on later thought. Democritus (c. 470-c. 400) was the founder of the *atomic theory*. He regarded *atoms* and the *void* as the only existences. Everything, even the phenomena of life and thought, was to be explained as the result of the action of these atoms, moving in the void. Atoms, he held, were eternal, being neither created nor destroyed, though the combinations in which they occur constantly changes. Atoms were infinite in number. Motion of atoms had always existed. Democritus held that by consequence there must have been an infinite number of worlds which passed through their various stages of growth and decay. Everything, in his system, could, he held, be explained on purely mechanical grounds without introducing any idea of an intelligent cause working toward an end.

§ 3

THE REVOLUTION IN GREEK THOUGHT

THE earlier and simpler phase of Greek thought terminates with the fifth century in a thinker of an entirely different type, Socrates (470-399 B.C.). His name is associated with the advent of a great intellectual revolution, among the greatest that the world has seen.

The position of Socrates was one of scepticism as to the validity of all human knowledge. The direction of his thought and of that of his followers was thus little determined by physical philosophy. The Greek philosophers before the time of Socrates had largely concentrated on the *physis* of the sensible Universe and had developed a system of *physics*. The overwhelming interest of Socrates, however, was in the direction of *conduct*. In seeking guidance for right conduct he was led to suppose that the soul of man partook of the divine. He reached the conception of an immortal soul, the existence of which he maintained as an article of faith, but not of knowledge. He thus rejected the whole structure that the physicists had reared. Nor would he have any parley with the conflicting theories of these men, of whom "some conceived existence as a unity, others as a plurality; some affirmed perpetual motion, others perpetual rest; some declared coming into being and passing away to be universal, others altogether denied such things." He thus regarded as futile all attempts "to pursue knowledge for its own sake." Nevertheless, he recognised the existence of 'Practical Wisdom' (*phronēsis*), lead-

ing to right action. It was *phronēsis* against *physis*. This *phronēsis* bears some relation to the *Wisdom* of the later Jewish 'Wisdom Literature.' In due course of time *phronēsis* went through a process of development something like that of *physis* and tended to personification under various names.

The Socratic revolution depressed for a time the activity of Greek physical philosophy. It did not, however, destroy it. Out of the conflict between the Socratics and the physical philosophers arose the main streams of later Greek thought. One of these streams exhibits a development of the characteristic Socratic interest; this stream leads on to Plato and to the *doctrine of ideas*. In its ultimate development it expressed itself as a complete indifference to worldly happenings. Its final stage in the pagan world is associated with the 'Neoplatonists.' On the other hand, the physical philosophy, having recovered from its submergence, revived in even more dogmatic form and became associated with the school to which Epicurus (342-270 B.C.) gave his name. The Epicurean school had many adherents down to the latest period of pagan antiquity. It is significant that both the Neoplatonic and the Epicurean schools became inimical to science, while neither was conducive to the current practice of religion. The subsequent development of both science and religion is thus historically associated with other systems of thought which chose a *via media*: for science that of the Peripatetics and their successors in after ages; for religion that of the great Judæo-Christian system of thought.

The thought of Plato (427-347 B.C.), like that of his master, Socrates, was dominated by the ethical motive. Convinced, like his master, that Truth and Good exist and that they are inseparable, he embarked on an inquiry which had as its object to expose, account for, and resolve into one comprehensive theory the discrepancies of ordinary thinking. During this process

he developed a doctrine destined to be of great moment for the subsequent relations of religious and scientific thought. It is the so-called *doctrine of ideas.*)

The nature of this doctrine and the manner in which Plato reached it has been briefly set forth by his pupil Aristotle (384-322 B.C.). "In his youth," says Aristotle, "Plato became familiar with the doctrines of certain philosophers that all things perceived by the senses are ever in a state of flux and there is no knowledge concerning them. To these views he held even in later years. Socrates, however, occupied himself with ethical matters, neglecting the world of nature as a whole, but seeking the universal in these ethical matters. It was he who fixed thought for the first time on *definitions*. Plato accepted his teaching but held that the problem applied not to anything perceived by the senses but to something of another sort. His reason was that the common definition could not be a definition of things perceived by the senses, because they were always changing. Things of this other sort he called *Ideas* and things perceived by the senses, he said, were different from these *Ideas* and were all called after them" (Aristotle's *Metaphysics*, i. § 6).

Thus *ideas* or *concepts* became for Plato something very concrete, while our impressions of the material universe, *percepts*, became something very vague. Such a theory, it is evident, could easily ally itself with religious teaching which deals with concepts. Historically the great religions have not been backward in profiting by the mighty assistance which the greatest of all philosophers could lend. It is not, however, our concern here to follow that development of Plato's influence. To scientific advance, on the other hand, his attitude was by no means helpful.

Plato expresses a great admiration for mathematical principles and he regards mathematics as exhibiting that type of certitude and exactness to which other studies should conform. Now mathematics relies for the

material on which it works upon something of the nature of Plato's Ideas. Many of Plato's thoughts assume a mathematical guise and he exhibits at certain times a view which seems to approach that of Pythagoras (sixth century B.C.), who had attached a moral and spiritual value to numbers. This Pythagorean attitude to numbers was, in fact, very largely assumed by Plato's successors, the so-called Neoplatonists.

The general attitude of Plato was less favourable to the physical sciences. He naturally could not regard with aught than scorn the materialistic theories of earlier writers. Of these Democritus was to prove the most influential and at his views we have already glanced. Plato, nevertheless, speaks with respect of Hippocrates, the very type of scientific investigator in antiquity. His respect in this matter was, however, devoid of any inclination to follow in his footsteps. Nor is this to be wondered at, for he assigned a relatively unimportant place to phenomena, and was quite without those qualities which lend themselves to patient, inductive observation.

Nevertheless, the great philosopher could not refrain from producing something in the way of a cosmic theory. The work in which this cosmic theory appeared, the *Timaeus*, gives us a picture of the depth to which natural science can be degraded by a great mind in its endeavour to give a specific purposive meaning to all parts of the universe. The trend of Platonism in general, and of the schools that arose from it, was always away from observational science, though not unfriendly to mathematical development.

The physical philosophers of the fourth century, of whom Aristotle is the greatest and most permanent, were more successful than Plato in their efforts at constructing a coherent and lasting cosmic theory. We may glance at the picture of the material universe presented by Aristotle. That great thinker, weak, perhaps, in mathematics, was himself a first-class

naturalist. The cosmic scheme that he produced, unlike that of Plato, absorbed a vast mass of observational material, notably in the department of biology. Yet the bases of the scheme were certain preconceived notions which did not and could not depend upon observation. Into this scheme observations had to be fitted. The difficulty of fitting them represents a struggle between the observational and theoretical interests which is a prototype of that so often encountered in later centuries.

We may observe here that the general history of later Greek physical philosophy presents certain features which are closely parallel to that of science in the West in modern times. The philosophical scheme once established becomes part of the religious systems of thought and any attempt to disturb it is resented. An effort, too, is made to confine the activities of the men of science to the adjustment of the details of the scheme. An attempt, for instance, such as that of Aristarchus of Samos (c. 250 B.C.) to show that the earth moves round the sun is denounced by the Stoic Cleanthes (c. 301-232 B.C.) as impious, just in the manner that Galileo was denounced by the theologians in the seventeenth century.

Let us now turn to the actual Aristotelian system of *physics*. That system, in a more or less modified form, was absorbed by the various philosophical schools of antiquity and played a very important part in the history of Christian thought. It is therefore necessary to note its fundamental bases. These may be briefly drawn up thus:

- (a) Matter is continuous
- (b) All matter is made up of combinations of the four elements, Earth, Air, Fire, and Water, each of which in their turn contain the four *qualities*, hotness, coldness, dryness, and moisture, in binary combination.
- (c) The earth is a sphere. It is fixed as the centre of the universe, which is itself spherical.

(d) Stars and planets move with uniform velocity in concentric circles round the earth.

(e) Circular movement is the most perfect conceivable and represents the changeless, eternal, and perfect order of the Heavens as contrasted with the mutable, mortal, and imperfect order that prevails on this our earth.

(f) The universe is finite.

This system lasted unshaken for 2,000 years, roughly from 350 B.C. to A.D. 1650. But while universally accepted there were certain corollaries to it that obtained less wide or more partial acceptance.

LATER GREEK THOUGHT

By the end of the fourth century B.C. ancient science had reached the zenith of its creative activity. Nevertheless much work was done during the two centuries which followed. This was due to the Alexandrian school, with which names such as those of Euclid, Herophilus, Archimedes, Eratosthenes, and Ptolemy are associated. The members of the school, able though they were, give the impression of being *epigoni*, heirs or successors to a great heritage, an inspiring vision. These men were the successors of the Lyceum of Aristotle and of the Academy of Plato in the same way as their royal masters were successors of the Empire of Alexander. Archimedes, who was an Alexandrian only by the association of his friendships, stands out as the great and brilliant exception. We must remember, however, that a complete and coherent scheme of the physical universe had been already evolved which was not fundamentally altered by later investigations. That scheme had been set forth in the Aristotelian writings. Now the corner-stone of the Aristotelian scheme, as indeed of nearly all Greek physical philosophy, was the view that substance is not *created*. The point is repeatedly raised by Aristotle himself, and is perhaps inherent in the scientific method of investigating the universe. It is a postulate without which the continuous application of the scientific method is perhaps impossible. Matter is, for the ancient physical philosophy as for modern science, uncreatable and indestructible. This is the condition under which alone investigation of the material universe becomes worth while. "That

nothing," says Aristotle in his *Metaphysics*, "comes to be out of that which is not, but everything out of that which is, is a doctrine common to nearly all the natural philosophers." Nor is the position altered, save in name, by those conceptions, whether modern or ancient, which would reinterpret matter in terms of physical forces.

The Greek scientific scheme would doubtless have found itself in violent conflict with the religious system of the day if formal religion among the Greeks had reached the high rational level that it had attained among the Hebrews. We shall see the clash in later Jewish and early Christian thought under Greek influence. Among the pagan Greeks, however, little opposition is encountered until very late times. With Greek popular religion in so relatively primitive a state, there were, in fact, few points of contact between priest and philosopher. The two went their ways almost independent of each other. The philosophy of the age carried with it certain religious implications and satisfied the religious aspirations of those who studied it. For such there was little need for and no enmity to the popular religion. Thus, though there was no open conflict between religion and science in the pagan world, yet the popular religion continued to be undermined by the physical philosophy.

There were, however, certain necessary corollaries to the physical philosophy which ultimately brought to an end not only the popular religion but ancient civilisation itself. In a world in which, to use the phrase of Lucretius (c. 60 B.C.), 'nothing is ever begotten of nothing by divine will,' and in which 'things cannot then ever be turned again to naught,' it must needs be that all things act by rules inherent in everlasting matter. What is there then left that is ourselves, our real inner self-conscious selves? The question was variously answered by various schools of thought. It is a question that is asked to this day when we put it

that a man is the combined product of his heredity and his environment and ask what else is left of him. The Stoic philosophy, the most popular and the most 'religious' of the later pagan schools, would reply that what is left to the man himself is the will, which gives him the power to play his part like a man, doing his duty in that walk of life to which Providence has called him. We are just parts of Nature. "Thou hast subsisted as part of the whole. Thou shalt vanish into that which begat thee, or rather thou shalt be taken again into its Seminal Reason by a process of change," so muses the Stoic Emperor, Marcus Aurelius (A.D 121-180). Such philosophers would take little interest in this tyrant Nature. Why should they? In our age men learn the ways of Nature that they may control her, but the time for that was not yet. Epicurus would have us know only so much about her as would remove from us all fear of supernatural interference. Stoic and Epicurean literature show, therefore, in later antiquity a flagging of scientific curiosity. Men were weary of the world. For what reason should they seek to know Nature more intimately—Nature the compassionless, the tyrannical, the cruel?

With this fading of interest among philosophers, something had happened also among the more ordinary run of men that turned them from investigating Nature too nearly. Into the welter of philosophic sects, of contending oriental cults, of decaying scientific interest, of rhetorical exercise, of the hundred intercrossing currents that made up the spiritual life of later antiquity, there came a new ray of hope. That hope suggested not, indeed, that man might control his fate but that he might at least come to foresee it and so prepare himself the better for it. It was that strange system, Astrology, that gave this new power. Astrology came to the West from the East and was eagerly absorbed into popular as well as into philosophical thought. Its application was essentially a task

for the 'Chaldean' specialist, to whom alone the details themselves were of interest. The future, it was believed, could be read, and once read—who cared then for the wretched rules by which it had been read? They were at best but means. Leave them to the Chaldeans! It was the end that mattered

The astrological system of antiquity was only a formal statement of those beliefs concerning the nature and working of our mundane sphere that had been fostered by such science as had survived. In the concentric universe of Aristotle and Ptolemy and their followers the outer spheres of the stars and planets must surely influence and control the central globe of the earth and with it the fate of man. So, at least, the Stoics saw it and faith in astrology became part of the Stoic creed. It gave an inevitable interrelationship of all things. In the presentation of the world thus made, there was no room for those anthropomorphic gods, belief in whom was still urged by the priests and held to by the multitude. The spread of science, or of what passed for science, had led at last to a complete breach between the official faith and the opinions not only of the educated classes but of all intelligent men. The idea of the interdependence on one another of all parts of the universe, produced a new form of religion. The world itself must be divine. "Deity," says Pliny, "only means Nature." God, if God there be, had made the world and in making it had made its laws. It was the laws that were the effectual rulers, and it was by those laws that the pagan world was hypnotised. Why should men of flesh and blood regard a far-off, frigid lawgiver, who could not and did not have regard to them?

The position was the opposite of that of those later eighteenth-century Deists who 'sought through Nature, Nature's God.' It was precisely Nature that made God meaningless.

Science, linked with Stoicism, thus assumed a fatal-

istic and pessimistic mood. "God is outside the world and could not be expected to care for it," says Pliny. The idea of immortality seems to him but the 'childish babble' of men possessed by the fear of death. After death, so Pliny, like Lucretius, would have us believe, man is as he was before he was born.

In the utter inevitableness of the action of that law Lucretius the Epicurean claimed to find comfort from the unknown terror. Yet for the Stoic, if his inmost heart were revealed, it remained a cruel law. Even the *Meditations* of Marcus Aurelius are writings of terrible gloom. What must have been the outlook of a less noble soul? The Stoic vision, we must remember, was very different from that given by the spacious claim of modern science which explores into ever wider and wider regions of space and time and thought. It was an iron, nerveless, tyrannical universe which science had raised, in which man had been caught and by which he felt himself fettered, imprisoned, crushed. The Roman had forsaken his early gods, that crowd of strangely vague yet personal beings whose ceremonial propitiation in every event and circumstance had filled his fathers' lives. He had before him an alternative of the oriental cults whose gods were but mad magicians—a religion unworthy of a philosopher—and the new religion of science whose God, he now saw in his terror, worked by mechanical rule. He had abandoned the images of his ancient deities to embrace the feet of *Natura* whom he believed to be a lovelier goddess, and lo! it was a pitiless machine to which he found himself clinging. His soul recoiled and he fled into Christianity. Science had induced that essential pessimism which clouds the thought of the later pagan world. It was reaction against this pessimism which led to those great spiritual changes in the midst of which Antiquity went up in flames and smoke.

§ 5

LATER JEWISH AND EARLY CHRISTIAN THOUGHT

IN the earlier books of the Old Testament there is no conception of natural law. Natural phenomena and especially the more dramatic events, the thunder and the whirlwind, drought and flood, plague and famine are the result of God's immediate action. "The voice of the Lord is upon the waters: the God of Glory thundereth" (*Psalm xxix. 3*). Even in a less anthropomorphic atmosphere there is still no element intervening between God and natural phenomena. All are the result of direct action by Him

"Who hath measured the waters in the hollow of His hand,
And meted out heaven with the span
And comprehended the dust of the earth in a measure,
And weighed the mountains in scales
And the hills in a balance.

* * * * *

It is He that sitteth upon the circle of the earth,
And the inhabitants thereof are as grasshoppers;
That stretched out the heavens as a curtain,
And spreadeth them out as a tent to dwell in.

* * * * *

I am the Lord, and there is none else,
There is no God beside me.

* * * * *

I form the light and create darkness;
 I make peace and create evil;
 I the Lord do all these things."

(*Isaiah* xl. 12, 22; xlv. 5, 7.)

Such a work as *Job* reveals a new development. Critics would place this book certainly later than 400 B.C., and therefore after *The Sacred Disease*. The author of *Job* has attained to a definite recognition of natural law. The argument of the book is, indeed, based on the wonder and majesty of the laws by which God rules His world. If Job does not comprehend those laws, how can he hope to comprehend the purpose that is behind them? It is with irony that the Almighty demands:

"Dost thou bind the cluster of the Pleiades
 Or loose the bands of Orion?
 Dost thou lead forth the Mazzaroth in their
 season?
 Or canst thou guide the Bear with her train?
 Dost thou make the heavens to know the laws?
 Dost thou establish the dominion thereof in the
 earth?"

(*Job* xxxviii. 31-33.)

These very laws are used as proof of the power, wisdom and goodness of God, for the same reason that they are invoked in the *Bridgewater Treatises* of more than two thousand years later. The recognition of natural laws in *Job* is doubtless the result of contact with Greek thought.

In the yet later 'Wisdom Literature,' the contact with Greek thought is yet closer. The characteristic features of Greek physical philosophy have been absorbed, and peep out unmistakably here and there. The relation of God to the natural laws has also become modified. Not only does He not act on the world directly, but He has become further removed

therefrom than in *Job*. There is another existence that governs the laws of Nature and indeed makes them, it is that elusive 'Wisdom,' an entity almost as hard to define as the Greek *physis* which it in some ways resembles. Wisdom has some of the attributes of Deity. She is omniscient, omnipotent, 'she reaches from one end of the world to the other and ordereth all things well' (*Wisdom* viii. 1). So far from God acting directly, it is 'by His *Word* that He made all things and by His *Wisdom* then He formed man' (*Wisdom* iv. 1).

Moreover, this new Jewish mode of thought has become self-conscious and polemic. It sets itself deliberately over against Greek thought. Among the Greeks various 'first principles' had been adopted. Thales had proposed 'water,' Heracleitus 'fire,' Pythagoras the 'circling stars,' Anaximenes 'air,' yet other philosophers some vague essence that may perhaps be translated 'winds.' Finally the new astrological science coming in from Babylon had suggested the complex mathematical order of the heavenly bodies as the motive power of all things. The *Wisdom of Solomon*, which was written in Alexandria about 100 B.C., inveighs against all these:

"Surely vain were all men in their natures, and
without perception of God
Who could not, from the good things that are
seen, know Him that is.
Neither by giving heed to the works did they
recognise Him who hath wrought them,
But either fire (*i.e.*, Heracleitus), or wind or the
swift air (*i.e.*, Anaximenes),
Or circling stars (*i.e.*, Pythagoras), or raging
water (*i.e.*, Thales), or the lights of heaven
(*i.e.*, the astrologers),
They deemed the gods which govern the world."
(*Wisdom* xiii. 1-2.)

There are other channels of later Hebrew thought which are even more in the direct line of our story. The best representative of this later Jewish movement is the Alexandrian philosopher Philo contemporary with Jesus Christ.

Philo was a thinker who drew on many sources, but his general trend was along Platonic lines and far removed from the study of phenomena. He therefore represents a further separation of religion from science. Religion and science had touched each other in the days of the 'Wisdom Literature.' It is evident that in Jewish feeling, so far as it is exhibited by Philo, they are again diverging. Philo was conscious of being a 'philosopher' in the Greek sense, and he betrays this consciousness in his works in a way that is not exhibited in any earlier Jewish writings.

Just as the Stoics treated Homer allegorically in their search for a justification of their views, so dealt Philo with the Old Testament. This often leads him to what we should now regard as an extreme straining of the text. This process of allegorisation, though very characteristic of a large amount of subsequent theological writing, is devoid of interest for our purpose. It takes religion ever further from the scientific standpoint. It is the *mechanism* of Philo's attempt to deal with the problem of Creation that alone brings him into contact with our subject.

On the one hand, Philo had before him the biblical Hebrew doctrine of Creation. This doctrine treats God as a separate existence outside the world which He had produced at a definite date by definite acts and which He continued to guide in every detail. On the other hand, Philo, basing himself on Platonic thought, developed a conception of a God without emotions, without attributes and consequently without name, changeless and imperceptible by man, self-sufficient. This God is simply existent and has no relations to

any other being. Such is the God of the Platonic idea. Such a God could not act upon the world nor create nor guide it, though he might set it going once and for all. The old Hebrew view and that of Philo were incompatible.

Under these circumstances Philo resorted to a device which can be traced in one form or another as far back as Heracleitus (535-475 B.C.). He introduced an existence between God and the world. *Physis*, *phronēsis*, *wisdom* were similar previous attempts. Philo's device was the *logos*. The concentration of attention on these and similar theological complexities was bound to turn men's attention away from the study of phenomena.

There was, however, a yet further reason for the 'flight from phenomena' in late Jewish and early Christian thought. Ever since the Socratic revolution a section of thinkers had regarded the material universe as containing something essentially without worth or even evil. The members of this school opposed *Nous*—that is, Mind, Soul, or Spirit—to *Hylē*—that is, Brute Matter. The distinction had been emphasised by certain interpreters, at least, of the Platonic doctrine of Ideas. The worthlessness and evil character of the material world fitted in well with the Jewish doctrine of the Fall. The view had, therefore no difficulty in entering Jewish thought, and through it Christian thought. Though Philo is at some pains to avoid the conclusion that the world is necessarily evil, it may be doubted whether his efforts are successful. Thus the 'sins of the flesh' became a theological commonplace which passed over naturally, along with the *logos*, into Christian thought.

St. Paul's teaching was greatly influenced by this idea of the physical basis of sin. "We know that the Law is spiritual: but I am carnal, sold under sin" (*Romans* vii. 14). Under these circumstances Chris-

tianity for a time turned entirely away from phenomena. St. Paul does not conceal his contempt for Greek physical philosophy. It is not so much that it is false as that, for him, it is trivial and irrelevant. Being irrelevant, with the fearful issue of salvation before him, it was also impious.

"When ye knew not God, ye did service unto them which by *physis* are no gods. But now, after that ye have known God, or rather are known of God, how turn yet again to the weak and beggarly *elements*, whereunto ye desire again to be in bondage?" (*Galatians* iv. 8-9).

With this contempt for the study of phenomena was soon, however, welded another belief very widely current in Judæo-Christian literature. The end of the world was a constant preoccupation of that literature and is described over and over again in lurid colours. Now, in much of Greek physical philosophy, as in that of Democritus, this world is but one of a long series of worlds. The end thereof would mean but the beginning of another world like to it. This did not fit Judæo-Christian ideas. If the world which had been created was to come to an end, a conception of the destruction of the elements themselves must be adopted. "The day of the Lord will come as a thief in the night; in the which the heavens shall pass away with a great noise and the *elements* shall melt with fervent heat, the earth also and the works that are therein shall be burned up" (*2 Peter* iii. 10). So long as that idea was prominent in men's minds there could be no serious attention paid to phenomena. 'The day of the Lord' rang the death-knell of science. The development of Christian and of Jewish theology ceases, at this point, to have an interest for our purpose.

THE MIDDLE AGES

DESPITE the spread of philosophy based on science, the observational activity of antiquity was slowly dying in the pagan world from about 100 B.C. About A.D. 200 it expired with Ptolemy and Galen. The decay of observation, as we have seen, was the result of internally acting causes. In origin it had nothing to do with Christianity, which was not yet in a position to have its full effect on pagan thought.

But Christianity did come as a protest and a revolution against the prevailing and extremely pessimistic outlook. Men had lost interest in the world and Christianity brought them something to live for, it brought a *cause*. It was natural under these circumstances that Christian thought should oppose the philosophical basis of pagan thought. In this sense early Christian thought was certainly anti-scientific and exhibits an aversion to the view which places the whole of man's fate under the dominion, the inescapable tyranny, of natural law. It is, however, essential to remember that the Early Church, in developing this opposition, was not dealing with living observational science. The conflict was simply with a philosophical tradition which contained dead, non-progressive, misunderstood scientific elements. The conflict in the Early Church, therefore, though exceedingly interesting in itself, is of little importance for our subject and we can afford to pass it by.

The centuries wear on. Christianity becomes more firmly established as the state religion. At last the need

for a coherent philosophical system becomes more pressing. During the earlier Middle Ages this need is met, on the scientific side, largely by that bizarre work of Plato, the *Timæus*. As time passes, Aristotelian elements become more and more prominent, and by the thirteenth century these Aristotelian elements come to occupy the main field. The great system of Catholic philosophy, of which St. Thomas Aquinas (1225-1274) was the leading architect, was built upon the recovered writings of Aristotle. The work of Aquinas is merely the greatest and most lucid effort of a process that had been going on for centuries. His *Summa Theologica*, regarded as a sustained intellectual effort, must be considered one of the most remarkable and fatiguing performances that the human race has yet achieved. As an investigation of evidence for the views that it sets forth, the modern working scientist will pass it by.

But although the Church professed to accept the Aristotelian philosophy, there were certain points in that philosophy which could not be effectively incorporated into a Christian system. Many elements of the Aristotelian philosophy were, of course, incompatible with the biblical account. Such, for instance, was the spherical earth. Details of this type were glossed over without grave difficulty. The incompatibility was ignored, or the biblical account was held to be allegorical or to have some mystical or moral meaning, or again, it was pointed out that the Bible was not written for the purpose of teaching science and that such apparent inconsistencies were without profound significance. Allegory was often invoked. On the whole Christianity plus Aristotelianism explained more than either system by itself, and there was therefore no reason why men should abandon either, still less both. Nevertheless, in the Aristotelian philosophy there certainly were very disturbing elements which might have led to profounder conflict. Such, for instance, was the basic Aristotelian view of the

indestructibility and uncreatability of matter, with the corollary that the Universe itself is uncreated and timeless.

If the actual words of Aristotle had been confronted with the biblical phrases the result would have been a very serious clash. But, in fact, this contrast could hardly be made directly. The access of the medieval scholastics to the Aristotelian writings was very precarious. To begin with, the writings themselves are obscure and their language is very difficult even to a Greek scholar, and Greek scholars were extremely rare during the Middle Ages. Further, though attempts were made by Aquinas and others to have translations of Aristotelian works made direct from the Greek, these translations were most imperfect, and were, moreover, very rare. Even Aquinas was unable to employ them to any large extent. The overwhelming majority of medieval Aristotelian translations and commentaries were made not from the Greek but through the intervention of Arabic or Hebrew commentators.

During the Middle Ages the tradition of Greek learning was mainly in the keeping of people of Arabic speech, and largely resided with the Jews so far as Europe was concerned. Among these 'Arabians' and 'Arabists' there was a difference of opinion as to the interpretation of the Aristotelian philosophy. One great group, followers of the Mohammedan philosopher Averroes (1126-1198), held that the world was eternal. That view was shared, in a more or less veiled manner, by a number of Christian writers, but was clearly heretical and could never be formally accepted by the Catholic Church. The other interpretation of the Aristotelian record represented the world as created. This view was presented by the Jewish writer Maimonides (1135-1204), whose account was generally current in Christendom. Thus Maimonides came to exercise an immense influence on Christian

scholasticism. Aquinas, who depended largely on Maimonides and similar writers, became represented as the protagonist against the 'atheistical' Averroes. Opposition to the great Moslem thinker was, moreover, intensified by his denial of the persistence of the individual soul. Aquinas held, however, that the temporal character of the world could not be proved but must be accepted as an act of faith.

With our improved understanding of the Aristotelian writings we can now say that the Maimonidean party was mainly wrong in its interpretation and the Averroan party mainly right. But such was the prestige of Aristotle's name that any view had to claim that it was based on Aristotle to have the least chance of a hearing. The versions of cosmology and cosmogeny that reached the West labelled with the name of Aristotle were travesties of the real teaching of the master.

The Middle Ages were on somewhat surer ground in their account of the Aristotelian physics. Here at least they came fairly near to understanding Aristotle. But the medieval Aristotelian physics, however interpreted, cannot be regarded as partaking of the nature of a science. It was an accepted doctrine, part of the tradition of antiquity. No attempt was made, or could be made, to put it to the test of experience, nor was it in any sense an organically growing body of knowledge. The great and important contest that arose concerning the interpretation of Aristotelian doctrine exhibits at times the appearance of a conflict between the religious and the scientific standpoint. That appearance is illusory. The conflict was not of faith *versus* observation, but of faith *versus* faith.

Moreover, the scholastic's universe, it must be remembered, so far as it was material, was limited. The outer limit was the *primum mobile*, the outermost of the concentric spheres of which the Aristotelian world was composed. Of the structure and nature of all

within the sphere of the *primum mobile* Aristotle and Ptolemy had equipped him with a definite scheme. The task of medieval 'physics' was to elaborate that scheme. The medieval world thus knew nothing of that infinite sea of experience on which the man of science nowadays launches his bark in adventurous exploration.

Yet it is a fact that man is an inquisitive, an observing, a classifying animal. Scholasticism could not and did not alter his nature; it could only mask it and overlay it. Precisely in the period when the respect for ratiocination and the indifference to nature had reached their zenith among the learned, the craftsman asserted his humanity. The great theological movement of the thirteenth century reared vast cathedrals, monuments of what the Faith meant in those days. That faith adorned them with images, beautiful if you will, but such as never were on land or sea. Those dislocated joints, those impossibly attenuated bodies, those fantastic anatomies, are noble in their artistic expression, but they tell their own tale of ignorance of the world without. But look at the capitals of those columns or the stone frames of these anatomical monstrosities and you will see something different. You will see ivy and vine, buttercup and columbine, growing, twining, shooting as they do in the craftsman's own garden. The mason is a better naturalist than the saint, the professor, or the architect. Natural curiosity, the mother of science, is awakening from her millennial slumber.

There are other minor arts—*e.g.*, that of miniature, in which the love of nature early asserts itself. The complete story of the birth of naturalism in medieval art has yet to be written. When we have such a work in our hands it will provide us with the introductory and perhaps the most fascinating chapter in a great History of Modern Science. Nor was there long delay before the affection for the outer visible world spread

to other and higher walks of life. It had early expressed itself in the career of St Francis, and it was not long in entering the schools themselves. The literature of the later scholastic centuries is inconceivably tedious to those who are not by temper in sympathy with its special themes. Yet even that literature is relieved by an occasional rare and precious ray of nature study.

It is an amusing reflection on the incompleteness of all philosophical systems, to recall that Albertus Magnus (1206-1280), the teacher of Aquinas, who perhaps more than any man was responsible for the scholastic world-system, was among those few medieval writers who were real observers of nature. To love the world around and to watch its creatures is, after all, of the very essence of the human animal. *Naturam expellas furca, tamen usque recurret.* Albert, scholastic of the scholastics, drowned in erudition, the most learned man of his time, reviver of the Aristotelian cosmology, the typical medieval philosopher, has left us evidence in his great works on natural history that the scientific spirit was again astir. As an independent observer he is not altogether contemptible. This power in him marks the beginning of the modern scientific movement. It was, however, centuries before observational activity obtained sufficient momentum or coherence to affect the religious standpoint.

Albert was not alone in his observations. Other observers were about, and some of them made discoveries of no mean importance. During the thirteenth century there was much interest in optics; the attention devoted to the subject led, in about the year 1300, to the application of lenses—which had been known to the Arabian writers—as spectacles. A similar process had led at an even earlier date to the adaptation of the magnet to the mariner's compass. These are discoveries of first-rate importance and we cannot pass them by in silence. But—and this is where we sense

the characteristic medieval atmosphere--these *discoveries led to the production of no general laws*. The lens led to no advance in the doctrine of refraction or in the theory of light. The compass revealed nothing of the nature of terrestrial magnetism to the medieval thinker. They were on the level of *inventions* rather than definite steps in scientific progress. The actual application of these discoveries was far more important to the men of the time than were the principles involved. If we seek for interest in the eliciting of new general laws of nature we shall have a long and fruitless hunt in the vast wilderness of time that we call the Middle Ages.

THE CLOSE OF THE MIDDLE AGES

WHILE the Middle Ages present instances of discoveries and inventions and are not without traces of real scientific advance, they are singularly devoid of any activity in the discovery of new natural laws. It is such general ideas that alone bring science into relation with religion or philosophy. The existence of observational activity devoid of scientific elements is particularly evident in the last phase of medieval science. The point may be further brought out by adducing special instances.

Thus, consider the three great departments of Anatomy, Astronomy, Botany. Dissection of the human body was practised systematically from the thirteenth century onward and important additions to the knowledge of the time were made by several investigators. Despite the results that these men obtained, the physiological theories of Galen prevailed without question in the textbooks of the time. Again, Astronomy was the main scientific interest of the Middle Ages and important new observations were recorded. Yet none left the least impress on astronomical *theory*. Botany, again, was the chosen study of the physicians whose remedies were chiefly of vegetable origin. Manuscripts of the fourteenth and fifteenth centuries contain many beautiful figures of plants. The magnificently illustrated works of the so-called 'German fathers of Botany' in the first half of the sixteenth century contain illustrations of herbs which in accuracy and beauty are unsurpassed even to this

day. Yet these works are devoid of theories on the great biological topics.

During the period between the beginning of the thirteenth and the beginning of the sixteenth century there was a series of movements of vast importance for the history of culture but which we shall be able to pass over rapidly. These movements were (*a*) the firm establishment of the Inquisition, (*b*) the religious upheaval known as the Reformation, and (*c*) the Revival or Renaissance of Learning. We may consider them in this order.

The Inquisition as a regular and legally established method of confirming faith and uprooting error makes its appearance in the thirteenth century. Our horror at its methods, our indignation at its injustice, our detestation of its blood-stained and infamous history, must not mislead us into regarding it as an attack on the experimental method. It is true that in the sixteenth, seventeenth and eighteenth centuries the activities of the officers of the Inquisition were directed to the suppression of scientific views held to be dangerous to faith. In the centuries that preceded, however, no such tendency can be distinguished. The reasons for this are simple. During those earlier centuries, on the one hand, experimental methods produced no conclusions dangerous to current theology, and on the other hand, no officer of the Inquisition ever grasped the nature of the scientific method. So far as the Middle Ages are concerned we can therefore put aside the Inquisition as irrelevant to our discussion.

We may turn now to the great religious movement, the Reformation, which has determined the religious geography of Europe. Those who profess the reformed faith naturally regard their point of view as truer and more reasonable than the faith which it displaced. But Truth and Reason are not in themselves science, and search how we may we shall fail to find any special influence of the experimental philosophy in the

establishment of the Reformed Religion. The most that can be urged is that the unsettling discoveries of the new-born experimental method helped the ferment of discontent which expressed itself in religious matters as the Reformation. Even that interpretation somewhat strains the facts. In truth, the reforming leaders from Wycliff to Calvin showed no more sympathy with the experimental method than did their opponents. Thus for our purpose the conflict between Catholic and Protestant is of little, if any, significance.

It may be a cause of surprise that we propose to omit discussion of the Revival of Learning as irrelevant to our subject. Yet so far as the Renaissance meant anything for science it meant a rebirth or resurrection of *ancient* science. The earlier humanists were as little sympathetic to, or understanding of, the experimental method as were the great religious leaders. The backward-looking habit, strong in man from his nature, was enforced, not weakened, by these humanists. From Petrarch onward they were ever brooding on the past that had been Greece and Rome. Their attitude was often not without opposition to the current religion, but again that conflict has nothing to do with the relation of religion and science. Improved access to Greek works of observational science gradually became possible through the agency of Humanism. On the renewed acquaintance with Greek science the modern application of the experimental method was based, but Humanism as such hardly comes into our story. After all, the scientific views of the Middle Ages were substantially those of the classical decline, and it was long before any great change was made in them by the revival of antiquity. For our theme the Revival of Learning is therefore most reasonably considered as an incident of the later Middle Ages.

Looking back on the Middle Ages we can discern only one figure of first-class importance in whom

interest in the discovery of new laws is prominent. In our search it would be easy to be misled by words. The interest of the scholastic period was in classification, and we encounter much discussion on the classification of the 'sciences,' as, for instance, in the pages of Vincent of Beauvais (1190-1264). But if you seek science as we understand it, even in its most elementary form, in these vast encyclopædias you will seek in vain. Albert, as we have seen, and a few other scholastic writers, took a real interest in Nature, but the character of that interest almost expressly excluded the drawing up of general laws. "It is not enough," says Albert, "to know in terms of Universals, *but we seek to know each object's own peculiar characteristics, for this is the best and most perfect kind of science.*" Albert was, in practice, content enough to take his Universals from Aristotle. In the writings of Roger Bacon alone do we encounter an unmistakable demand for the search for natural laws.

The works of Roger Bacon (1214-1294) are open to much criticism, which they have not failed to receive. It is pointed out that personally he was jealous and censorious, that he demands of others standards which he does not apply to himself, that despite his own constant demand for an investigation of Nature and despite the legends and his own claims as an investigator, when we look for evidence of his scientific achievements we are met with something very like a blank. But the claim that he realised in advance of his age the nature and application of the experimental method is, I think, clearly established. He frequently uses the phrase *experimental science*, which is for him the sole means of obtaining knowledge. "All sciences except this," he writes, "either merely employ arguments to prove conclusions, like the purely speculative sciences, or have universal and imperfect conclusions. Experimental science alone can ascertain to perfection what can be effected by Nature, what by art, what by

fraud It alone teaches how to judge all the follies of the magicians, just as logic tests argument."

Now, it is very important for us to note that there is no trace in Roger Bacon's writings of any consciousness of opposition to religion. He thinks he is writing in support of the faith. We to-day are well aware that, in some at least, religious faith has been shaken by the course of science of which Bacon may be regarded as one of the prophets. To Bacon, however, it is not at all evident that this would or could be so, and there is nothing in any of the works by him that would lead us to consider that by his contemporaries he was regarded as heretical or unorthodox in matters of religion. Since his day many legends have arisen around his name, but there is not the least historical evidence that his views were held to be subversive of religion by his contemporaries. Bacon was certainly in bad odour with the authorities of his order but of Bacon as a heretic or as a protagonist of any war against religious belief we hear never a word. Thus the very interesting incidents of his life and work, important for the history alike of philosophy, of theology and of science, have little significance for the relation of these departments to each other.

In a later generation and even more clearly than Roger, a herald of the scientific dawn was the Cardinal usually known as Nicholas of Cusa (1401-1464). This interesting and many-sided thinker is important for us for more than one reason. We may glance first at his scientific standpoint and achievements. He ranks as a real scientific investigator, for he clearly perceived the nature and some of the possibilities of the experimental method and did not hesitate to draw general laws from his conclusions.

Nicholas was a trained mathematician and took much interest in astronomical and calendarial matters. He proposed a reform of the calendar similar to that which was adopted by Pope Gregory. Among the

most arresting of the passages in his works is a statement in the course of a philosophical treatise that "I have long considered that this earth is not fixed but moves, even as do other stars . . . To my mind the earth turns upon its axis once in a day and a night." He has left us a short experimental sketch *On experiments with the Balance*. The basis of this work is that whenever weight is lost or gained the loss or gain can be accounted for by investigation. This is little else than the older Greek scientific view which formed the basis of the Epicurean philosophy. His manner of working out the details is most interesting. For example, he shows that earth in a confined vessel in which plants are growing loses weight. He infers that this weight is gained by the plants. He suggests also that the plants gain in weight from something that they take from the air, and he affirms that the air itself has weight. The book is written in what, for the time, is a revolutionary spirit. To find a parallel to it one would have to go back to Greek science, a subject in which Nicholas was deeply interested, or forward to Galileo. Nicholas had the germs of the idea of the Reign of Law, and on this account his theological and philosophical position is of special interest to us.

The theological standpoint of Nicholas is set forth in his work *De Docta Ignorantia*, which has nothing to do with the absurdity of erudition, as its name might be thought to imply, but concerns itself with man's essential incapacity to attain to absolute truth. It was followed by the *De Conjecturis*, in which he comes to the conclusion that all knowledge is but conjecture and that man's wisdom is to recognise that he can know nothing. From this attitude of apparently pure scepticism he escapes by the mystic way. God, about whom we can know nothing by experience or reasoning, can be apprehended by a special process (*intuition*), a state in which all intellectual limitations

disappear. We need follow Nicholas no further on his theological path, but we may remark that he dimly foresees the approaching clash between the scientific and the religious standpoints, and that he solves the difficulty in the way chosen by many other scientific men since his day. He accepts the existence of two forms of experience: an outer, subject to natural law, about which we may reason, and an inner which has no relation to such law and is above and beyond reason. The position, if rigidly maintained, is impregnable from the scientific side. Between it and science there could never be any real conflict.

THE DAWN OF MODERN SCIENCE

THE period that represents the growth of the modern attitude to science—say from about 1500 to about 1700—may be roughly divided into two. During the earlier period ending about 1600 the experimental method, though gradually more and more recognised in practice, continues to be regarded as an uncertain instrument. It is still largely a subject the nature of which it is for the philosophers to discuss. Those who occupy themselves with the actual business of observation, men of science as we call them to-day, are few and their work is as yet inconspicuous. During the later period the validity of the experimental method becomes recognised as universal, within its own field, by an ever growing band. This later period is definitely opened by Descartes and Galileo. It reaches consummation in the work of Newton.

Pietro Pomponazzi (1462-1525), Antonio Telesio (1482-1534), Bernardino Telesio (1509-1588), Francesco Patrizzi (1529-1597), Giordano Bruno (1548-1600), Francis Bacon (1561-1639), Tommaso Campanella (1568-1639), Marin Mersenne (1588-1648), Pierre Gassendi (1592-1655), culminating with René Descartes (1595-1650), represent a long line of thinkers, all of whom had some share in forging the great instrument of scientific thought, yet none of whom, save the last, have left any deep impression on the actual body of scientific knowledge. Associated with this army of philosophers is a small body of actual scientific workers, of whom the most prominent are Johannes Müller of Königsberg ("Regiomontanus," 1436-1478),

Nicholas Copernicus (1473-1543), Andreas Vesalius (1514-1564), and Tycho Brahe (1546-1601), culminating with Galileo Galilei (1564-1642) and Johannes Kepler (1571-1630).

A glance at the history of these will leave us in no doubt that the danger to the prevalent religious systems of the day is now becoming apparent. Pomponazzi dies without the consolations of the Church; Telesio arouses the anger of the Church on behalf of its cherished Aristotelianism, and a short time after his death his books are placed on the Index; Bruno, the exponent of the philosophical implications of Copernicus, is burnt for his pains; Campanella, after twenty-seven years in prison, is detained for three more in the chambers of the Inquisition; Mersenne escapes criticism by professing the narrowest theological orthodoxy; Descartes, despite his claim to be regarded as a faithful follower of the Church in which he had been born, consistently finds discretion the better part of valour on all questions which involve theological judgment.

In great contrast to such men as these are the character and fate of the small band of practical investigators. Regiomontanus completes his work under the patronage of a Cardinal but unnoticed by the theologians; Copernicus and Vesalius lay their axes to the tree of Aristotelian science and go their ways in peace; Tycho, in a Lutheran country, prepares the path for Galileo without suffering hindrance. The escape of these gives the greater significance to the fate of Galileo, for he it was who finally polished the new intellectual instrument which since his day has been ceaselessly applied by men of science.

Among the earlier practical exponents of the new experimental method we will select for special discussion two brilliant practitioners, Copernicus and Vesalius. By a curious coincidence these two—both men of one book—published the great works with

which their names are associated in the same year, 1543, which perhaps better than any other may be regarded as the birth-year of modern science

Copernicus, much the older, much the less striking, much the less of an 'observer' in the modern sense of the word, was also much the more conservative of the two. Despite the vast change introduced in his name, he was himself more in line with such comparatively conservative scholars as Nicholas of Cusa and Regiomontanus than with the more revolutionary thinkers such as Campanella and Telesio, who were perhaps more typical of the thought of his time. No man was ever more "academic" than Copernicus, and he inherited the learning of the Italian Universities, at several of which he studied. Despite—or perhaps because of—his learning, he was not to any large extent a first-hand observer. He had, it is true, taken a small number of observations of eclipses and planets, but for the most part his results were obtained in the study. In his dedication to the Pope he recounts that he was induced to seek a new theory of the heavenly bodies by finding that mathematicians differed among themselves on this subject. It is evident, both from his long delay in publication and also from certain notes in the preface to his work *On the Revolutions of the Celestial Orbs*, that he had anticipated opposition on religious grounds, which indeed the book immediately encountered. Yet, in fact, when we come to examine the work, the actual changes that he introduces are not as great as we might expect. It is true that he makes the earth move round the sun. He retains, however, the ancient theory of the uniform circular motion of the heavenly bodies, nor does he make any attempt to treat the fixed stars as placed other than at a uniform distance from the centre of the universe, which thus remains spherical and finite. It is only in the bold speculations of Giordano Bruno, suggested, it is true, by the work

of Copernicus, that we meet with a limitless universe. It is thus in the century which followed its publication, rather than its own time, that the Copernican hypothesis became intimately bound up with the relations of religion and science.

Vesalius was in almost every respect a contrast to Copernicus. Young, ardent, and combative, his life's work was wellnigh complete at twenty-eight, and its effective and creative part was packed into the four years that preceded the publication of his *Fabric of the Human Body* in 1543. The contents of that great work were delivered in the form of lecture-demonstrations to crowded audiences. It contains an enormous number of first-hand observations, accumulated while working under the most extreme pressure. The work at one stroke placed the investigation of the structure of the human body in the position of a science in the modern acceptance of that term. But vigorous and fearless in the demonstration of observed fact, Vesalius becomes timid and ineffective in the discussion of theory. He had not hesitated to attack the accuracy of the anatomical observations of Galen. The physiology of Galen, however, occupied in the mind of the age somewhat the same position as the physics of Aristotle, and Vesalius left the physiological theory of Galen even more intact than Copernicus left the physics of Aristotle.

A word must be said of the background of Vesalius, which presents a great contrast to that of Copernicus. If Copernicus represents the learned side of Renaissance activity, Vesalius represents its artistic side, and in this relation his work is of peculiar interest. Labouring as an anatomist and as an artist in that age, he could not help thinking always of the *end* to which man was made. Despite his occasional revolt from Galen as an observer, he was yet steeped in the Galenic teleology. But, with an artist's mind and eye, Vesalius transmuted that age-old, moss-grown scheme into

something higher and nobler. For him man is a work of art, God the artist. Vesalius was no philosopher, so that we must not seek in his pages for any formal justification of this view. But so much he says and says well, over and over again. Men and women he saw, as it were, as 'studies' for God's great design Imperfect studies indeed. Unlike Galen, Vesalius did not harp constantly on the perfection of man's form. He had only the bodies of criminals and worn-out paupers on which to practise his art. Yet even these were worthy of attention as setting forth, however distantly, the design in the mind of the Godhead. To reach closer than these poor corpses to that great design was the real aim of Vesalius. We think of biological investigations in terms of evolution and we ask constantly Whence? and How? The biological science of our day and especially its evolutionary doctrine has answered these questions in a way far other than that conveyed to us by our religious tradition. But to Vesalius no such discrepancy was present. He did not think of man's body in terms of evolution but in terms of design, and his questions, had he been philosophically articulate, would have been Whither? and Why? To these questions he and his followers, for generations to come, had no answer save that provided by the religious system of their day. Thus, though Vesalius profoundly altered the attitude towards biological phenomena, he yet prosecuted his researches undisturbed by the ecclesiastical authorities.

To us who live only a generation or two after the disturbances of the spirit caused by the Evolution controversy, it may seem that biological rather than physical science is the department likely to clash with the claims of traditional religion. Yet historically this is not the case. The successors of Vesalius continued to prosecute their studies until the nineteenth century, unnoticed or even directly aided by the Churches. It was the cosmical speculations of the astronomers and

physicists, not the investigations of the biologists, that attracted attention of the less welcome variety.

Giordano Bruno (1548-1600), who was no practical scientist, had eagerly incorporated into his often fantastic philosophy the ill-worked-out conclusions of Copernicus. Despite the allegorical presentation of his thoughts, his works leave us in no doubt of the vehemence of his attack on established religion. His denial of particular providence leads him to a rejection of miracle, to the identification of liberty and necessity, and to the doctrine of the uselessness of prayer. Bruno in his search for unity regards God as the universal substance. Nominally adopting the Copernican theory, he modified it fundamentally. Praising the genius of Copernicus for its freedom from prejudice, he regrets that the astronomer was more a student of mathematics than of Nature, and was therefore unable to free himself from untenable principles. The limitation of the sphere of the fixed stars was obnoxious to Giordano, and he removed the boundaries of the world to an infinite distance, in accordance with the principles of his philosophy.

Giordano was burned at the stake at Rome, after seven years' imprisonment, on 17th February, 1600. In the same year the experimental era was ushered in with the work of William Gilbert, *On the Magnet*, in which he not only demonstrates experimentally the properties of magnets but also shows that the earth itself is a magnet. In the same year Tycho Brahe handed over the torch to Johannes Kepler. Tycho was the last of the older astronomers who worked on the Aristotelian view of circular and uniform movements of heavenly bodies. Kepler was the real founder of the modern astronomical system. The period from 1600 lies with the new men, Galileo and Kepler among astronomers and physicists, Harvey among biologists, Descartes among philosophers. The year 1600 thus represents as real a division as any that we can expect in the history of thought.

THE FIRST PHYSICAL SYNTHESIS

THE seventeenth century opened with an extraordinary wealth of scientific discovery. As we glance at the mass of fundamental work produced during that period, we perceive that the major departments of science, as we know them to-day, are becoming clearly differentiated. The acceptance of observation and experiment as the only methods of eliciting the laws of nature reaches an ever-widening circle.

We cannot help noting that the biological advances, and even the introduction and revelations of the microscope, leave the theological world almost unmoved. Even the idea of the automatism of animal movements and reactions developed by Descartes, and further extended later in the century, have little or no effect on the position. It was much the same with the work of the chemists. Far otherwise was it with the physical and astronomical discoveries. From the first these attracted theological attention.

Galileo Galilei (1564-1642) lived a long life of almost unparalleled intellectual activity. Many of the products of his genius were of immediate practical application, many more involved profound modification of the current scientific opinions, yet others struck at the very basis of the general beliefs of the day. It is with the last class alone that we are here concerned.

The early training of Galileo had been along strictly scholastic and Aristotelian lines, as is shown by his notebooks written in or before 1584. Soon after this date he began a systematic experimental investigation

of the mechanical doctrines of Aristotle. There resulted the *Sermones de Motu Gravium*. This work was circulating in manuscript in 1590 though it did not appear in print until 250 years later. The work contains a number of objections to Aristotelian teaching, together with a record of experiments on the rate of acceleration of falling bodies. These doctrines were announced from his professorial chair and in 1591 were demonstrated from the leaning tower of Pisa. By that famous experiment he displayed, in the most public manner, the error of the Aristotelian view that treated the rate of fall as a function, not of the period of fall, but of the weight of the object. Galileo's critical attitude to Aristotle, the bulwark of the scholastic system, earned him the virulent enmity of the academic classes. Immediately it cost him his chair. He had, however, made the first definite breach in the Aristotelian armour.

The investigations of Galileo during the next twelve years, though fruitful in scientific discovery, yielded little that was important for our theme. Galileo's work of 1604 was more revolutionary. In that year a new star appeared in the constellation known as 'Serpentarius.' He demonstrated that this star was without parallax. It must inferentially be situated beyond the planets and among the remote heavenly bodies. Now this remote region was regarded in the Aristotelian scheme as absolutely changeless. Though new stars had been previously noticed, they had been considered to belong to the lower and less perfect regions nearer to earth. To the same lower region, according to the then current theory, belonged such temporary and rapidly changing bodies as meteors and comets. Galileo had thus attacked the incorruptible and unchangeable heavens. Small wonder that the spirit of the time was against him.

In 1609 Galileo made accessible two instruments that were to have a deep influence on the subsequent

development of science, the telescope and microscope. The latter instrument was for long employed almost exclusively by biologists, and Galileo was no biologist. It is with the former instrument that his name is most frequently associated. His first discoveries made with the aid of the telescope were issued in 1610. That year was crowded with important observations which we may consider briefly.

The first yield of the telescope was an immense number of hitherto unobserved fixed stars. It was soon found that these were at least ten times as numerous as those that had been catalogued. The more conspicuous star clusters were found to contain many stars too faint for recognition by the naked eye. Parts of the Milky Way and some of the nebulous patches were resolved into congregations of stars of various magnitudes. The surface of the moon, so far from being smooth and polished, was found to be 'very similar to the earth,' rough with depressions and high mountains. The height of the lunar mountains was even measured by means of the shadows that they cast. The four satellites of Jupiter were discovered. The comparison of their movements to that of our moon suggested resemblances of our earth to the planet Jupiter. The outermost of the known planets, Saturn, was investigated. Peculiar appearances in him were noted by Galileo, though their interpretation as rings was the work of Christian Huygens (1629-1695) at a later date.

Among the most important of all the observations of the year 1610 were those on the inner planets and notably on Venus. It had been a real objection to the Copernican hypothesis that if the planets resemble the earth in revolving round a central sun, they might be expected to be luminous only when exposed to the sun's rays. In other words, they should exhibit phases like the moon. Such phases in Venus were now actually observed and described by Galileo.

At this time, though Galileo had earned the enmity

of the Aristotelians, and had been attacked by a certain number of hot-headed clerics, he was not yet in bad grace with the heads of the Church. In 1610 he first observed dark spots on the surface of the sun. These, he noted, narrowed continuously as they approached the edges of the sun's disc. He rightly regarded this process as foreshortening and as indicating that they were on the surface of the sun's orb. The date and circumstance of the announcement were unfortunate, since they involved him in a controversy with a powerful Jesuit rival who not only claimed priority of observation but also put another interpretation on the spots. The controversy spread far beyond its original focus. We shall not follow it. An aspect of the dispute, however, was the question of the habitability of the moon and planets. His critics believed this view a natural corollary of Galileo's development of the Copernican hypothesis which he had now openly espoused. The habitability of the moon was contrary to what was regarded as Aristotelian and Christian doctrine.

Thus became united against Galileo a variety of interests. The band of Academic Aristotelians had long been fuming against him, and Jesuits and some political churchmen now joined them. To them were united many of that intellectually timid and novelty-hating class that forms the mass of every population in every age and is by no means rare in university circles. From at least 1614 onward sermons were preached against him. The opposition gained force. The matter came before the Inquisition early in 1616 and Cardinal Bellarmine was directed "to admonish Galileo to abandon these opinions and, in the event of a refusal, to command him to abstain altogether from teaching or defending or even discussing them. If he do not acquiesce he is to be imprisoned." A few days later a decree was issued ordering the work of Copernicus to be 'suspended till corrected.'

During the following years the agitation against Galileo gathered further strength. In 1623, however, something was hoped by him and his supporters from the accession to the Papal throne of Urban VIII., who, as Cardinal, had appeared not unfriendly to scientific research in general and to Galileo in particular. In 1624 Galileo visited him but failed to obtain promise of any toleration, even in a passive form, for the new doctrines. In this very year Galileo published his *Il Saggiatore*, a work which contains a conception of the greatest import for the subsequent development of science, and one, moreover, which was destined to colour deeply much of the philosophical thought of later ages. This conception was the drawing of a sharp distinction between those qualities in objects susceptible of exact numerical estimation and those which cannot be treated in this way. We may quote his words:

"No sooner do I form a conception of a material or corporeal substance, than I feel the need of conceiving that it has boundaries and shape; that relative to others it is great or small; that it is in this place or that; that it is moving or still; that it touches or does not touch another body; that it is unique, rare, or common; nor can I, by any effort of imagination, disjoin it from these [primary] qualities. On the other hand, I find no need to apprehend it as accompanied by such conditions as whiteness or redness, bitterness or sweetness, sonorousness or silence, well-smelling or ill-smelling. If the senses had not informed us of these [secondary] qualities, language and imagination alone could never have arrived at them. Wherefore I hold that tastes, colours, smells, and the like exist only in the being which feels, which being removed, these [secondary] qualities themselves do vanish. Having special names for them we would persuade ourselves that these [secondary qualities] have a real and veritable existence. But I hold that there exists nothing in external bodies for exciting [the

secondary qualities] tastes, smells, and sounds, but [the primary qualities] size, shape, quantity, and motion. If, therefore [the organs of sense], ears, tongues, and noses were removed, I believe that [the primary qualities] shape, quantity, and motion would remain, but there would be no more of [the secondary qualities] smells, tastes, and sounds. Thus, apart from the [percipient] living creature, I take these [secondary qualities] to be mere words."

This distinction which Galileo makes so clearly between the *primary qualities* and the *secondary qualities* of bodies has been made by men of science ever since. Galileo was the prime mover of that development which is summed up in the phrase *Science is Measurement*. As to whether men of science have been right or wrong in their view that these primary qualities have a reality that the secondary qualities have not, we need not for the moment consider. It is evident that the universe of our experience is almost entirely made up of secondary qualities. The fact that men of science dwelt chiefly on something else, something which ordinary men do not ordinarily consider, separated them from their fellows. Since the time of Galileo men of science have formed a sort of priesthood which has been, not infrequently, opposed to another priesthood. Nor has the distinction which Galileo made remained with the working men of science. Through Thomas Hobbes (1588-1679) and John Locke (1632-1704) in England, and through Marin Mersenne (1588-1648) and René Descartes (1596-1650) in France, it passed into general philosophy.

For six years after Galileo's interview with the Pope in 1624 for the purpose of obtaining toleration for his cosmic views, the philosopher was almost silent on the subject so far as public utterances were concerned. Then in 1630 he broke silence. Between that date and 1633 was played the final scene in the great drama of his contest with the Church.

By the beginning of 1630, after many years' work, Galileo had at last completed the composition which was finally published as the *Dialogue on the Two Chief Systems of the World*. The systems referred to in the title were, of course, the Ptolemaic and the Copernican.

Quite apart from the discussion of the relative position of earth and sun in the universe, the *Dialogue* is the consummation of the labours of Galileo in that it seeks to present the doctrine of the uniformity of the material universe. This point of view is so familiar to us nowadays as to be a part of our manner of thinking. We are brought up to it from our earliest years. The only occasions on which it is ever questioned by civilised men of our own time are, on the one hand, in the discussion of the nature or reality of miracles, and, on the other hand, in the discussion of the relation of mind and matter. But in the early seventeenth century it was not so. The Aristotelian conception of the universe still ruled supreme. According to that view the events in the high supra-lunar spheres—celestial physics as we may call them—were of a very different order to our earthly happenings—terrestrial physics. A large part of mediæval philosophy may indeed be regarded as debate, prolonged through hundreds of years, of the relation of celestial physics to terrestrial physics. That there was a difference between the two had hardly been questioned till the time of Galileo. Even Galileo was in no strong position to discuss celestial physics. It is of interest, however, that he throws out a definitive suggestion that they can be discussed on the terrestrial basis:

“Since, as by a unanimous conspiracy of all the parts of Earth for the formation of its whole, those parts do congregate with equal inclination and, ever striving, as it were, at union, adapt themselves to the form of a sphere, so may we not also believe that Moon, Sun, and the other members of the solar system

(*corpi mondani*) are likewise of spherical form by a concordant instinct and natural concourse of all their parts? And if any of their parts were violently separated from the whole, might we not reasonably suppose that they would revert spontaneously by natural instinct? May we not therefore conclude that, as regards their proper motion, all members of the Solar System (*corpi mondani*) are alike?"

Galileo, having finished his *Dialogue*, obtained an interview with the Pope, who gave him to understand that no objection would be raised to publication if certain conditions were accepted. The more important of these may be thus set forth:

(a) The title must clearly indicate the character of the book.

(b) The subject must be treated from the theoretical standpoint and this must be clearly set forth in the preface.

(c) The book, being largely concerned with the tides, must be made to terminate with the following argument: "God is all-powerful. All things are thus possible to Him. Therefore the tides cannot be adduced as a necessary proof of the double motion of the earth without limiting His omnipotence."

The suggestions were accepted, as were some other minor revisions and alterations made by an official, and this great work was issued at the beginning of 1632. It is full of prophecies of the development of cosmic theory. We have seen something of its philosophical importance, and that in suggesting the uniformity of the material universe it foreshadows the conception of universal gravitation and with it the essence of the first law of motion to which we shall have later to refer. Oddly enough, it was not the sweeping generalisations on which Galileo's opponents seized; indeed, it may well be that they did not apprehend their significance. It was rather certain details opposed to the current view that specially raised their

animosity. We, therefore, turn to those elements in the work which had a more immediate effect on the attitude of the theologians.

The dialogue is represented as between three persons, an open advocate of the Copernican doctrine, an obtuse and obstinate follower of Aristotle and Ptolemy, and an impartial participator open to conviction. The demand that the Copernican view be treated as a mere hypothesis is but superficially complied with, and the terminal argument, though included in the discussion as Galileo had agreed, is treated with scant respect. The tone of the work, witty and biting, leaves no doubt as to Galileo's real opinions. The Aristotelian is represented as hopelessly stupid. The book claims acceptance of the Copernican view. In fact, however, it passes far beyond Copernicus, notably in the total rejection of the idea of the stars as fixed in a crystal sphere. The stars are held to be at inconceivable but varying distance from our earth, and the absence of visible stellar parallax is considered as due to the vastness of this interval. The actual measurement of the parallax of a fixed star was, in fact, not made until 1838, when it was achieved by Friedrich Wilhelm Bessel (1784-1846).

The *Dialogue* brought matters to a head. The Jesuits being especially occupied with teaching were specially enraged. In August, 1632, the sale of the book was prohibited and its contents submitted for examination to a special commission. They reported against Galileo. The end is well-known and we shall not discuss it here.

In character and temper Johannes Kepler (1571-1630) was almost as much a contrast to Galileo as was Copernicus to Vesalius in the previous century. Kepler, a German Protestant, a mystic and dreamer, essentially a mathematician rather than an experimenter, produced voluminous works that are now almost unread-

able. He stands over against Galileo, the Italian Catholic, with his clear cold intellect, his unrivalled experimental skill, his wit, and his great artistic and literary prowess. In sheer genius, however, the two men were not rivals but peers and comrades. On them, in equal measure, rest the foundations of the great physical synthesis.

Kepler's idea of the universe was, from the first, essentially Platonic, or perhaps we should say Pythagorean. He was convinced that the arrangement of the world and its parts must correspond with certain abstract conceptions of the beautiful and the harmonious. It was this faith that sustained him in his vast and almost incredible labours. In estimating those labours the reader may be reminded that he spent years of his life chained to the mere drudgery of computation, without any outside assistance and without any of the devices, such as mechanical computers or the use of logarithms, that lighten the task of the modern worker. Nothing but a burning faith could have made such drudgery possible.

We gain an insight into the transition state between the old and the new in which Kepler worked when we recall that his professed occupation was largely astrological calculation. Nor was he cynically sceptical as to the claims of astrology as were some of his contemporaries who earned their living thereby. Kepler sought in the events of his life a verification of the theory of the influence of the heavenly bodies. For this purpose he kept all his life what is nothing more nor less than an astrological diary!

Kepler adopted the Copernican view from an early date, and before 1595 he had turned his mind to the question of the number, size, and relation of the orbits of the planets. He was ever seeking a law binding the members of the solar system together. After trying various simple numerical relations, after attempting to fill the gaps by hypothetical planets, and

after discarding various other suggestions, he lighted, at last, on a device which satisfied him. There are only five possible regular solid figures (*i.e.*, figures with equal sides and equal angles), and there are only five intervals between the six planets that he recognised. As far as the calculations of Kepler extended at that time, the five regular solids could be fitted between the spheres of the planets thus :

Sphere of Saturn	
Cube	
Sphere of Jupiter	
Tetrahedron	
Sphere of Mars	
Dodecahedron	
Sphere of Earth	
Icosahedron	
Sphere of Venus	
Octahedron	
Sphere of Mercury.	

For the first time a unitary system had been actually introduced in an explanation of the structure of the universe. We may join the firm believer in revealed religion in smiling at this instance of human fallibility and presumption. Kepler had wrongly estimated the distance of the planets from their centre. The basis of this unitary system was a miscalculation! It endured but a day. But to Kepler who, like the mediæval thinkers, held that the universe was designed on a moral plan, these new mathematical relationships—false though we now know them to be—came as a confirmation of what he conceived to be the divine purpose. The regular solids, he observed, were of two classes, primary (cube, tetrahedron, dodecahedron) and secondary (icosahedron and octahedron), differing in various ways. What more fitting than that the earth, the residence of man created in God's image,

be placed between the two kinds of solids! The scheme, he held, was wholly consistent—nay, was confirmatory of—many of the tenets of his religious belief!

The fact that Kepler sought so persistently through all these years of labour for a simple mathematical scheme of the parts of the material world, and the fact that, having found one—though on a wrong basis—he regarded it as fitting in with the scheme which he had conceived of the moral world, would suggest certain reflections on the workings of the mind itself. Whatever reality may be, it would seem that we are so made as to aspire towards a reasonable interpretation of the universe. Great religions all attempt to provide this. All become skilfully rationalised. It is because science disturbs part of the rationalised field that religion resents its intrusion. The mind recoils from a dualistic universe, and rationalised religion usually seeks to minimise even that remnant of dualism, the conception of a Devil or Archfiend. It is easy for us now to regard the opponents of Galileo and Kepler as purblind fools and, moreover, base motives certainly prompted some of them. In essence, however, their opposition was the result of the reluctance of the human mind to adopt any teaching which disturbs its unitary conceptions. A reasoned view of the universe, physical and moral, had grown up during the Middle Ages. It would have been indeed a marvel if this had been given up without an embittered struggle.

Despite the demonstrated error in his first attempt, Kepler still pursued the main object of his life, the foundation of an astronomy in which demonstrable causes should replace arbitrary hypotheses. The next topic that he set himself to investigate, with this end in view, was the relation of the distances of the planets to their time of revolution round the central sun. It was clear that the time of revolution was not pro-

portional to the distance. For that the outer planets were too slow. Why was this? "Either," he said, "the moving intelligence of the planets is weakest in those that are furthest, or there is one moving intelligence in the sun that forces all round, but most the nearest, languishing and weakening in the more distant by attenuation of its virtue by remoteness." In his use of such phrases as 'moving intelligence,' Kepler was simply employing the usual Aristotelian phraseology that had grown up during the Middle Ages. The conception was familiar to the mediæval philosophers, Christian, Moslem, and Jewish. Aquinas, Averroes and Maimonides all had a clear conception of intelligences moving the planets. They had derived this conception ultimately from Greek thinkers, and had adapted it to their various forms of theology. It was quite familiar to the scholastic thinkers of the sixteenth and seventeenth centuries.

As the sixteenth century turned into the seventeenth century Kepler received a great incentive to work by joining Tycho Brahe as assistant. By the death of Tycho in 1601 Kepler became effectively his literary legatee. The next nine years saw him largely occupied with the papers of Tycho and with work on optics, in the course of which he developed an approximation to the law of the refraction of light. In 1609 was issued his greatest work, the *New Astronomy, with Commentaries on the Motions of Mars*. It is full of important discoveries and suggestions. Among them we may enumerate the following:

(a) Important truths relating to gravity are enunciated—e.g., that the earth attracts a stone just as the stone seeks the earth, and that two bodies near each other will always attract each other if adequately beyond influence of a third body.

(b) A theory of the tides is developed in relation to attraction by the moon.

(c) An attempt to explain planetary revolutions

results in a theory of vortices not unlike that elaborated later by Descartes.

Above and beyond all, the work sets forth the cardinal principles of modern astronomy, the so-called first two planetary laws of Kepler by which

(1) Planets move round the sun not in circles but in ellipses

(2) Planets move not uniformly but in such a way as to sweep out equal areas about their centres in equal times

It was another nine years before Kepler enunciated his third law to the effect that

(3) The squares of the period of revolution round the sun are proportional to the cubes of their distance (1618).

For a thinker who understood these works of Kepler and the *Dialogues* and *Saggiatore* of Galileo, the Aristotelian physics and cosmology lay derelict. They could only be defended by such men as Galileo's accusers, who were unable or unwilling to investigate the matter for themselves. Every one of the foundations of the Aristotelian system (see pp. 21-22) had been undermined by Galileo or by Kepler and their place taken by an intelligible mathematical relationship. From now on the scholastic Aristotelianism was as much an embarrassment to official religion as the narratives of miracle became at a later date. It was, however, as hard for one section of the Church to rid itself of its scholastic heritage as it was for another at a later date to disembarrass itself of the dead-weight of miracle. There may have been truth in the words of Bruno: "Perchance your fear in passing judgment is greater than mine in receiving it."

THE REIGN OF LAW

RENÉ DESCARTES (1596-1650) was the first in modern times to propound a unitary and effective theory of the universe that became widely current. In the course of his life he made striking contributions both to scientific theory and practice, but these are less important for our purpose than his attitude toward religion and the cosmic theory that he developed.

In the year 1633 Descartes was about to publish his work which he termed *The World*, when he heard of the condemnation of Galileo. He withdrew the book and in the event his first publication was the *Discourse on Method*, in 1637.

From an early date Descartes felt great dissatisfaction with the results of the usual studies of his time. It seemed to him that there was no clear distinction between facts, theories and tradition. Want of clarity was always abhorrent to him. He attempted to divest himself of every preconceived notion and then to build up his knowledge. With this end in view he tells us in his *Discourse* that he made certain resolutions :

(a) "Never to accept anything for true which he did not clearly know to be such, avoiding precipitancy and prejudice and comprising nothing more in his judgment than was absolutely clear and distinct in his mind."

(b) "To divide each of the difficulties under examination into as many parts as possible."

(c) "To proceed in his thoughts always from the simplest and easiest to the more complex, assigning

in thought a certain order even to those objects which in their own nature do not stand in a relation of antecedence and sequence—*i.e.*, to seek relation everywhere."

(d) "To make enumerations so complete and reviews so general that he might be assured that nothing was omitted."

He believed that all truth that is ascertainable is so only by the application of these principles and thus applies as much in the sphere of religion as in mathematical or physical matters. In essence, therefore, revealed religion in the ordinary sense is superfluous. For him the fundamental test of truth is the clearness with which we can apprehend it. *I think, therefore, I am*, is the most clearly apprehended of all truths, and therefore personality cannot be an illusion. Similarly, to him the conception of the soul as separate from the body was clear and even obvious; therefore, he maintained, it must be true. Moreover, he considered that the mind could not create something greater than itself. Therefore the conception of infinite perfection transcending humanity must have been put into our minds by infinite perfection itself; that is, by God.

We may now turn to his conceptions of the material universe. The form of the world is inevitable, in the sense that, if God had created more worlds, "provided only God had established certain laws of nature and had lent them his concurrence to act as is their wont, the physical features of these worlds would inevitably form as they have done on our earth." He accepted the probability of creation of matter as a momentary act, but held that this act of creation was the same as that by which creation is now sustained.

Descartes regards the universe as infinite and devoid of any empty space. The primary quality of matter is extension, but there are also the secondary and derived

qualities of divisibility and mobility, which are created by God. We may connect the assertion of Descartes that divisibility and mobility are secondary qualities with the formulation of the law that matter, in so far as it is unaffected by extraneous forces, remains in motion or at rest.

He regarded matter as uniform—*i.e.*, made of the same basic stuff, though divided and figured in endless variety. Matter is closely packed, without any vacuum. Therefore the movement of any part of matter produces the movement of all matter. It thus follows that throughout the universe there are circular vortices of material particles that vary in size and in velocity. If one considers any limited part of the universe, as the particles in it whirl round in their vortices they get their corners rubbed off. These being rubbed finer and finer become a minutely divided dust which tends to centripetal action. This fine dust is the *first matter* and forms the sun and stars. The spherical globules whose corners have thus been rubbed off to form the *first matter* will have on the contrary a centrifugal action, and will form the *second matter*, which constitutes the atmosphere or firmament enveloping the *first matter*. The centrifugal tendency of the *second matter* produces rays of light which come in waves from the sun or the stars to our eyes. There remains the *third matter*, formed from those parts of the fine dust which get detained and twisted on their way to the centre of the vortex and therefore settle round the edge of the sun or star, like froth or foam. This *third matter* can be recognised as the sun-spots. Sometimes this *third matter* melts in the surrounding firmament, sometimes it forms a crust for the sun or star.

The vortices impinge on one another. As a star decays and as its expansive force becomes encrusted by the *third matter* another vortex will join with it. But if the central star be of greater velocity than the new vortex, it will dash through the new vortex and be

seen as a comet. Sometimes the encrusted star will settle in that part of the new vortex whose velocity equals its own, and is then seen as a planet. The planets of our solar system have all been caught up in the sun vortex.

For the completion of the system of Descartes, it was necessary for him to include the phenomena presented by living things. Here his descriptions illustrate how much in the dark his age was concerning the actual workings of the animal body.

"I remained satisfied with the supposition that God formed the body of man wholly like to one of ours, as well in the external shape of the members as in the internal conformation of the organs, of the same matter with that I had described, and at first placed in it no rational soul, nor any other principle, in room of the vegetative or sensitive soul, beyond kindling in the heart one of those fires without light, such as I had already described, and which I thought was not different from the heat in hay that had been heaped together before it is dry, or that which causes fermentation in new wines before they are run clear of the fruit. For, when I examined the kind of functions which might, as consequences of this supposition, exist in this body, I found precisely all those which may exist in us independently of all power of thinking, and consequently without being in any measure owing to the soul; in other words, to that part of us which is distinct from the body, and of which it has been said above that the nature distinctly consists in thinking—functions in which the animals void of reason may be said wholly to resemble us; but among which I could not discover any of those that, as dependent on thought alone, belong to us as men, while, on the other hand, I did afterwards discover these as soon as I supposed God to have created a rational soul, and to have annexed it to this body in a particular manner which I described."

He thus considered that man once existed without a rational soul and that animals are still automata. He knew, for instance, of the circulation of the blood, and, basing himself on it, he developed a most elaborate and carefully worked out theory of the action of the animal body. Man, however, differed from animals, at least in his present state, in the possession of a soul. This he believed to be especially associated with a particular part of the body, the pineal gland, a structure within the brain which, in his erroneous opinion, was not found in animals. In the pineal gland two clear and distinct ideas produce an absolute mystery. It is there that the mystery of creation is concentrated.

The Cartesian philosophy was the first complete and coherent system of modern times. It rapidly found adherents and spread in every country and was popular for several generations. In Descartes' native land it won its way even among churchmen. Gradually, however, the numerous physical errors on which it was based were exposed. Towards the end of the century the theory of vortices became quite untenable. It was, in fact, shown to be inconsistent with astronomical observation, and it did not fit in with either the cosmical system of Newton or the atomic theory which showed signs of revival. As an explanation of cosmic phenomena it could no longer be held. Moreover, the advance of physiological knowledge exposed the errors of Descartes in the interpretation of the workings of the animal body. Descartes, however, had laid the basis of modern philosophy, and from his time on there has been a continuous chain of thinkers who have claimed to interpret the world by the unaided powers of their own minds.

The crown of the scientific movement of the seventeenth century is the work of Newton (1642-1727). It happens that, while there is great difficulty in describing or discussing in non-technical language the cosmic

theories of Copernicus, Galileo, Kepler, and Descartes, the work of Newton, though no less technical and difficult, can be treated, for our particular purpose, in very brief fashion. Newton had before him the planetary laws of Kepler. He knew that for every planet the cube of the distance is proportional to the square of the time of its revolution, and he sought for some material cause for this. Such a cause he found.

Law had been traced in the heavens from an early age. The actual laws of planetary and stellar motion had been gradually developed from the simple astronomical theories of the ancients. New laws and new mathematical relationships of the heavenly bodies had been discovered. It had not yet, however, been shown that the natural laws that governed the heavenly bodies were in relation to the laws that govern earthly phenomena. To prove that that relation amounted to identity, to show that the force that causes the stone to fall is the same as that which keeps the planets in their path, was the achievement of Newton. Into the details of that achievement it is not necessary to enter here. But thereby Newton placed in men's hands a law whose writ was universal. The law of the heavens was now the law of earth.

During the century and a half that has elapsed since the publication of the law of universal gravitation, science has developed prodigiously along the same lines. In reliance on the universality of natural law the stars have been measured, weighed and analysed. The same scientific process, directed to our own planet, has traced its history, determined its composition, demonstrated its relation to other bodies. The investigations of the physicist and chemist have suggested a structure in terrestrial matter similar to that of the stars and suns. The whole has been reduced to a unitary system. Living things have been examined with greater and greater powers of analysis and mag-

nification. Among them, too, Law has been found to rule. The wild creature is a subject of law; the migration of the bird that is as 'free as air' can be predicted, at least statistically, as well as the process of digestion, as well as a chemical reaction.

During these two centuries and a half of vast experimental activity, wherever men have looked they have found law. It has always been a question of looking skilfully enough and patiently enough, for law to emerge. Yet it is true that there are certain important gaps which must be recognised. Thus, no real link has been shown to exist between the living and the not-living. Despite the extension of our knowledge of the physics and chemistry of the animal body, it yet remains that, as far as we can see, Aristotle was right in the sharp distinction that he made between life and not-life. But the acceptance of vitalistic theory does not imply the absence of natural law governing living things, and all seems as determinate within living things as outside them. There are laws of heredity as much as there are laws of chemical combination.

In the second half of the nineteenth century the view gained currency that species were impermanent and that man himself was descended from lower forms. Despite the commotion that this doctrine evoked, it introduced no fundamentally new factor. That human bodies may be investigated as though they were mechanisms, the laws of whose working are progressively discoverable, had been known in antiquity and had been amply demonstrated by such later workers as Harvey, Stephen Hales and Claude Bernard. That the structure of man was comparable to that of the lower animals had been recognised since the days of Galen, and earlier; it was the constant theme of Cuvier, Owen, and others. The introduction of a general law to correlate these conclusions is a

mere incident in the extension of the Reign of Law. The problem remained as before. After Darwin it was neither easier nor harder to explain how man could escape from the tyranny of natural law. Darwin doubtless brought the problem home to the ordinary man, he did not create it for the thinker.

It is said, and rightly said, that natural law is not absolute, that it exists in our minds and not in things, and that even in our minds it is subject to change. Philosophically this point is of very great importance, but it is irrelevant in connection with our conceptions of natural law over against revealed religion. It is a fundamental point that the external habiliments of religion, Revelation and all that proceeds therefrom, are as much *phenomena* as are chemical reactions, or the migrations of birds. These things, as being detectable by the senses, are subject to examination by the senses and analysis by scientific method. In the same sense as natural laws, they exist in our minds and even in our minds are subject to change.

The rapid introduction of new general laws covering an ever wider field have induced a feeling of insecurity as regards scientific conclusions. This feeling has been specially fostered by certain recent developments, which are sometimes presented as though undermining the Reign of Law. This doubt or hope is unfounded. It has always been recognised that Science is but a conceptual scheme which bears an uncertain relation to the percepts that it correlates. The relation of percepts to each other is, however, fixed and unaltering. When, for example, the substance with all the perceptual qualities summed up by the phrase *Hydrochloric Acid* is poured on the substance with the perceptual qualities of a *Carbonate* there follow perceptual qualities conveniently classed together under the term *Carbonic Acid Gas*. This is the sequence whatever our conceptual view of the event. It is unaltered by any atomic, ionic, electronic,

or other concept. The sequence is a Natural Law and so far as the Universe of sense is concerned such sequences appear to cover the whole field investigated. There is no area that has been exactly investigated that does not seem fully occupied by such sequences. But do there remain fields in which there is a reasonable presumption that such sequences are not universal? What in fact are the *exact* frontiers of the Kingdom of 'Law'? If we could define these frontiers, it seems to me, then and then only could we delimit the secular battle-front between Religion and Science.

During the last two hundred years, and especially during the nineteenth century, certain triumphs of physical science persuaded many that the world as a whole could not only be *described* but could also be *explained* as the working out of a mechanical rule. Among the scientific advances that lent themselves especially to this standpoint we choose a few for special mention. The revival of atomic theory early in the century, with its essential corollary of the indestructibility and immutability of matter, which followed the work of John Dalton (1766-1844), led, not unnaturally, to a revival of something akin to Lucretian philosophy. The discovery of the law of the conservation of energy by Joule (1818-1889) gave strength to this point of view. The same attitude was encouraged by the demonstration that the laws of chemistry and physics are effective in the workings of the animal body. The doctrine of evolution of living forms, which has attained wide vogue during the last seventy years, could, it was believed, be expressed in simpler terms, which have accordingly been more or less satisfactorily supplied. All of these movements have, however, ignored the fact that we only know of Natural Laws because of the peculiar structure of our minds. While, therefore, it is possible to express or describe Nature in terms which we ourselves provide, it is impossible to express or describe ourselves in

those terms. The thinker is thus always thrown back upon his own mind as the primary and inexplicable mystery.

We are not, however, concerned here with the solution of these difficulties, but with an historical statement of their development. The problem before the man of science during the last two hundred years has been to harmonise some form of religious belief with the deterministic view that seems essential to the practical working of the scientific method.

Historically men of science have found various modes of escape from the tyranny of determinism. The majority of men of science, like the majority of other men, have small philosophical powers. They, like most other men, have accepted their religion as they have found it. They have made their science their daily occupation without clear relation to their religious convictions. A proportion of scientific men, incensed by the mere discrepancy between the biblical and the scientific record, have abandoned more or less completely their relation to religion. A considerable section of these have ranged themselves as 'agnostic.' A considerable section of scientific men have tried to escape by an ever increasing simplification of religious doctrine. This line was adopted by the eighteenth century 'Deists' and by a considerable proportion of later theologians of various 'liberal' schools. The position of these has been much strengthened by certain modern philosophical movements.

Yet there remain two religious points of view that can hardly be affected by any extension of the scientific realm. The one would completely separate internal experience from external experience. The man who does that is safe; he has fled, as have many before him, to a haven of peace down the mystic way. The second would regard existence not so much as an individual thing but as as part of a greater whole, which is working out its own destiny in all things.

This combination of determinism and pantheism is a refuge not infrequently sought in antiquity, and even in the Middle Ages. To the same haven many a student of science has turned in modern times, from the days of Spinoza onward.